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Measuring Openness in Open Source Hardware with the Open-o-Meter

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Abstract

Open Source Hardware (OSH) products are those whose design are made publicly available so that anyone can study, modify, distribute, make, and sell them. In spite of the increasing popularity of this novel approach to intellectual property in product innovation, practice communities have faced difficulties to refine this concept into sharp and practical terms. There is to date no widely acknowledged criteria for determining whether a product is open source or not. Assuming OSH follows the same development path as Open Source Software and becomes a mainstream approach, the issue of conformance will also become critical for both producers and consumers. To address this gap, this contribution introduces a self-declared product openness marking scheme allowing to rate the openness of a product. Looking forward, it provides conceptual inputs for the future establishment of technical standards bringing clarity in this emerging and moving field.

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Keywords: open innovation; open design; standardization; certification; compliance.

1. Introduction

The term Open Source Hardware (OSH) refers to a product "whose design has been released to the public in such a way that anyone can make, modify, distribute, and use" it [1]. In other words, an OSH product is a physical artefact whose documentation is released under a license granting anyone with production and distribution rights, and is detailed enough to enable anyone to study and develop it further.

This concept results from a recent extension of the open source movement [2] outside software development into the realms of physical products. So far, producers of OSH have primarily been grassroots communities and non-commercial sectors such as NGOs and academia. The concept has not found its way to large-scale industrial cases yet. Nonetheless, its potential to disrupt dominant production systems has been a source of enthusiasm for both scientific and practitioner communities [3].

The emergence of OSH takes place in a context of increasing sensitization for social and environmental issues which led industries to integrate new requirements, such as eco-friendliness or fairness, in their production activities. The establishment of a consistent public discourse around these requirements was supported by the creation of clear product marking instruments such as ecolabels or self-declaration schemes. Such instruments allow decreasing information symmetries [4] and help consumers distinguishing honestly sustainable from "greenwashed" products.

This article discusses the feasibility of using such an instrument for labelling *openness* as well. This is motivated by the heterogeneous interpretations of OSH observed in practice [5] and by the blurred "openwashing" discourses paving the

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current industrial context where openness became a trending concept [6]. To the knowledge of the authors, there is to date no commonly acknowledged objective criteria drawing a clear line between OSH and non-OSH products. The establishment of such a criteria set is believed to be made difficult by the multifactorial nature of the concept of openness when applied to physical products. Rather than being a binary value, openness seems to spread along a continuum between two extreme states: fully closed and fully open. Against this context, the question seems to be less *whether* a product is open but *how* open it is.

In line with this, and as a contribution to set practicable standards in OSH, this article introduces a simple rating scheme—referred to as the "Open-o-Meter"—to assess the openness of a physical product. This scheme is seen as a step forward towards the establishment of clear standards of OSH for both practitioners and the general public.

The next section discusses the limits of existing standards calling for the definition of sharper compliance criteria. Section 3 investigates the implications of the OSH definition for product documentation and underscores the difficulty to approach openness in binary terms. Building on this, Section 4 introduces a pragmatic rating scheme to assess the openness of a hardware product on a simple scale. The limitations of this rating scheme are then discussed in the subsequent section and recommendations are made for further standardization efforts.

2. Limits of existing standards

A significant part of the effort to establish standards in OSH has been performed by the Open Source Hardware Association (OSHWA). It issued the programmatic definition cited as the first sentence of this paper, and which is, to the knowledge of the authors, the most widely acknowledged definition in both academic and practitioner communities. Since 2016, the OSWHA offers a self-certification scheme for product originators to signpost their compliance with this definition (http://certificate.oshwa.org/). It grants projects that have successfully completed the certification process with the usage of a legally binding certification logo on their OSH product. These standardization efforts are well acknowledged by practitioners and the certification scheme gained noticeable success: by end of May 2018 over 180 projects were listed in the OSHWA certification directory. Previous efforts to create a licensing scheme for OSH had been performed by the Open Hardware and Design Alliance (OHANDA) [7], an initiative which has been discontinued in the meantime.

A drawback of the existing certification scheme is that the definition it builds upon does not mean to chart what an OSH product is, but rather to provide a framework for open source hardware licenses. It focuses on the *licensing* aspects of product-related information disclosure and does not set concrete requirements regarding the *content* of the information to be disclosed. In other words, it does not tell what minimal set of information constitutes the "source" of a product.

This is consistent with the basic assumption underlying the concept of open source: that there is an entity called "source", which defines a product unambiguously, both in depth and entirety. It states that publishing this entity with sufficient licensing terms realizes the four freedoms associated with the concept of open source: the freedom to study, modify, make and distribute. These are reinterpretations of the four freedoms of free software stated by the free software definition: Freedom 0, the freedom to run the program for any purpose; Freedom 1, the freedom to study how the program works; Freedom 2, the freedom to redistribute copies; Freedom 3, the freedom to distribute copies of modified versions [2, 8]. These freedoms have been reinterpreted in the transition from immaterial intellectual property to tangible products. For example, running a program requires compiling the source code (an action alternatively termed as build or make in the software jargon). The freedom to run became the freedom to make the product, that is, to produce it. The freedoms of open source are also often referred to as 'open source rights.' Therefore, in the context of this article, and in accordance with observed practice, we use the terms 'rights' and 'freedom' indifferently.

The implicit assumption that there is a "source" is automatically satisfied in the case of software products, to which the concept of open source originally applies. Indeed, a program and its source are in immediate relation, a software product being the translation of a text written in programming language into a machine language by a deterministic algorithm. However, this almost bijective relation between the "source" and the product is not satisfied in the case of tangible products. On the contrary, the minimal information set allowing anyone to study, modify, make and distribute a piece of hardware tends to be a more varied bundle of documents the following section proposes to characterize.

3. Topology of OSH documentation

Fig. 1 introduces a typology of OSH documentation. It summarizes which documents can be reasonably considered as part of the "source" of hardware and which are their properties. The elements of this typology are either implied by the OSH definition or reflect the best practices of OSH documentation. Those were gained from the analysis of guidelines for practitioners as well as of a large number of OSH projects (see list in appendix). The elements of the OSH documentation typology are detailed in the following subsections.

3.1. Requirements in terms of documentation properties

The rights to study and make require access to sufficient documentation. Documentation needs to be accessible through "well-publicized means" (OSH definition, §1), for example as file downloads from the producer's website. It further needs to be obtained without condition in order to comply with the clauses of "no discrimination against persons or groups" and "no discrimination against fields of endeavor" (§7 and 8). Information further needs to be sufficient in order to allow "anyone" to study and make the design. Which minimal set of information is required to produce an artefact depends on who produces it. Obviously, not anyone has a high performance CNC machine tool for milling Inconel, so not anyone can fabricate every product. Hence, product documentation should reasonably target at the group of people who can have access to sufficient means of production to make this particular

Fig. 1. Topology of OSH documentation.

product. The minimal amount of information to provide is those this target group requires to fabricate the OSH product.

The right to modify requires sharing files in their original creation format rather than in export formats. Exporting information or creating particular views is inevitably bound with information losses, which makes further editions difficult if not impossible. For example, exporting parametric CAD models to mesh formats (STL, 3D-PDF) does not conserve the parameters and constraints, which are essential for editing the model geometry. The ability to edit these original files also requires access to adequate software. Here again, not everyone can afford every software or even the hardware running it. Consequently, there is a conflict between the requirement to share information in their original format and those of sharing information in affordable formats. Here again, a reasonable solution is to consider that “anyone” is a specific target group.

The right to distribute requires all product information to be released under license terms that grant anyone with the right to distribute and sell the documentation as well as the physical product this documentation describes.

3.2. Requirements in terms of documentation content

The right to study requires the publication of design files. Design files describe the relevant properties and working principles of a product and its components. In the case of electronics, these are schematics and board layouts. In the case of three-dimensional formed products, these are 2D or 3D CAD models and material descriptions, eventually structured by a nomenclature. This information is at best provided with textual descriptions indicating the significance of the models and the way they should be interpreted. Further textual description may be needed to understand the design rationale and product architecture, including for example a description of the product functionalities and application scenarios.

The right to make requires the publication of fabrication instructions backed by a bill of materials (BoM). The BoM can indicate for each component information such as part name and unique designation, technical specifications (e.g. tolerances), quantity, price, and reference to the corresponding design file (e.g. exploded-view drawing). Fabrication instructions can also include step-by-step assembly instructions, CNC production files (e.g. G-Code) or precursors (STLs), as well as relevant details such as machine parameters.

3.3. The implicit expectation of process openness

The concept of open source is not only generally acknowledged as an IP management model but also as a product development model [9]. The transparency and free disclosure of product-related information is expected to impulse participative, democratic, community-based forms of product development where any interested person can involve, regardless of their geographical or organizational background. This participative aspect is referred to by Huizingh [10] as *process openness* in contrast to *product openness*. While the OSH definition does not include process openness, the concept of open source itself is about transfer of technological knowhow from private to public. Therefore, OSH development is often expected to go along with transparent and participative product development processes. Process openness has been explicitly considered as an integral part of the open source concept in some academic reports [11, 12]. Nonetheless, previous research of the authors showed that, while both aspects are related, only a subset of OSH development projects implement processes openness [13].

Process openness does not automatically derive from product openness, but rather implies additional requirements beyond documentation considerations. Gathered best practices of process openness are to:

- Maintain channels for external people to raise issues and make propositions (e.g. issue tracking system);
- Share the product documentation on versioning systems enabling parallel work in distributed communities (e.g. Git-based version control systems);
- State which level of involvement from external volunteers is whished and provide guidance on how to contribute.

3.4. From requirements to compliance criteria

The elements summarized in the typology of OSH documentation are what makes it possible for anybody to exercise the four rights of open source. Considered individually, each of the elements of the OSH documentation typology are reasonable contributions to enable the four freedoms of open source. Considered altogether, these elements are associated with non-negligible workload. Requesting product originators to provide all of these may be an unrealistic expectation. And as a matter of fact, many OSH products are backed with documentation fitting with only a subset of the OSH documentation typology [5]. Unfortunately, it is not clear which of these elements need to be considered as mandatory which as optional. There is to date no ranking of these elements in terms of commonly acknowledged importance.

Additionally, not all elements of the OSH documentation typology are necessarily relevant for every product. For instance, the replication of simple hardware products made of one single part does not require access to any BoM or step-by-step assembly instructions. The level of detail of the product documentation also progresses along the product development process. For instance, in early design stages, the product documentation may not be mature enough for the product concept to be formalized into CAD files, assembly instructions and bills of materials.

4. Introducing the Open-o-Meter

The previous section showed that 1) the “source” of hardware can take various forms, 2) there is no commonly acknowledged importance order between these forms, and 3) it may be unrealistic to consider all of them as mandatory. This makes it difficult to draw a straight line between OSH and non-OSH products in practice. In response to this, this section suggests considering product compliance with OSH principles along an openness scale instead of in binary terms. It introduces an openness rating scheme referred to as the “Open-o-Meter” (OoM) using a cumulative point scale. It assesses products relatively to eight binary criteria addressing elements of process and product openness. These criteria are depicted in Fig. 2 and detailed hereafter.

4.1.1. Criteria definition

Five criteria address product openness:

1. Information contents are published under respectively relevant open-source-compatible licenses. That is, the documentation types of hardware components are released under an OSH-compatible license (e.g. TAPR) and the eventual software components are released under an OSS-compatible license (e.g GPL)
2. The design files of all product components designed by the originator (all technology types included) are made publicly available. When there are software components, source code is available, when there are electronic hardware components, ECAD files are available and when there are non-electronic hardware components CAD files are available.
3. A bill of material is available.
4. Assembly instructions are available.
5. All files, including design files, bill of materials, and assembly instructions, are released in their original format.

Three criteria address process openness:

6. All files are maintained in a version control system allowing interested people to edit the files.
7. Guidance is provided to external people on how to contribute to the product development
8. An issue tracking or equivalent system allows tracing tasks and improvement propositions.

OoM values are integers of [0,8]. A value of zero means the product complies with none of the openness criteria, and is therefore fully closed. A value of eight means the product complies with all best practices of open source hardware and is consequently fully open. Each OoM rating is to be considered together with contextual factors potentially reducing the maximum reachable value. For example, the product development may be in early stage so that no assembly instructions are available so far and the point for assembly instructions cannot be gained. Another example: the product is of low complexity (e.g. it is made of one part) so that there is no need for a bill of materials.

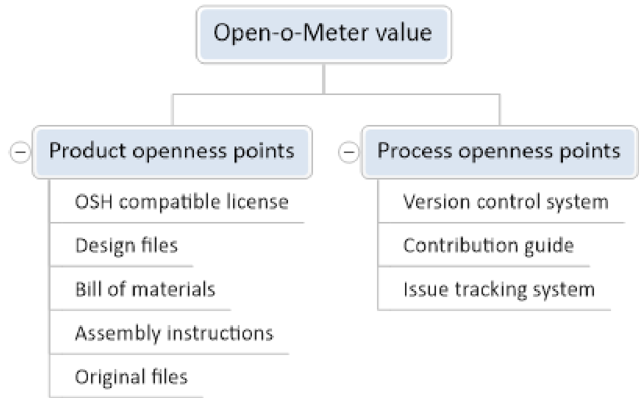

Fig. 2. Eight binary criteria constituting the Open-o-Meter.

4.1.2. Implementation examples

In the following paragraph, the introduced Open-o-Meter is illustrated against three OSH products. These products have been selected out of the pool of OSH products known by the authors to illustrate the whole range of openness measured by the OoM.

echOpen is a project aimed at "designing a functional low-cost (affordable) and open source echo-stethoscope" [14]. It was funded in 2014 as an open and collaborative development project involving physicians and engineers and released in 2016 a first medical image. While the targeted product (a hand-held portable sonographic equipment) is still in development, a first prototyping kit has been released under a self-developed OSH- and OSS-compatible licenses (+1pt). CAD and ECAD files as well as source code are available (+1pt). A BoM and assembly instructions are also available (+2pts). CAD and ECAD are provided in original formats; the BoM and the assembly instructions can be edited online (+1pt). The project website has a contributing guide (+1pt). Textual documentation can be edited online and files are versioned in a GitHub repository (+1pt), which implements an issue tracking system (+1pt). As a result of the above, echOpen's product openness is five and process openness is three. This results in an OoM value of eight, which is the highest reachable value.

inMoov is a fully functional design of "3D printed life-size robot" [15]. The project has been initiated in 2012 by the artist Gaël Langevin and was conceived as a development platform for academic and hobbyists audience. The humanoid robot has been replicated and customized several times. The product documentation is licensed under a CC-BY-NC license, which is not OSH-compatible since it does not allow commercial usage, and the software is not provided with a license (0pt). CAD and ECAD files as well as source code are available (+1pt). A BoM and assembly instructions are also available (+2pts). The assembly instructions and the BoM are static online content and CAD files are provided in export formats (0pts). There is neither a contributing guide, nor an issue tracking system, nor can be files edited by external people (3x0pts). As a result of the above, echOpen's product openness is 3 and process openness is zero. This results in an OoM value of three.

POM is referred to as "the world's first open-source mass market vehicle platform" [16] and is a joined project of Renault and Open Motors, formerly OSVehicle. The authors could not find any information beyond a declaration of intent to release in open source the platform of Renault's two-seat electric vehicle Twizy, which has been relayed in some media (e.g. [17, 18]). None of the OoM criteria could be satisfied by the available documentation, resulting in a OoM value of zero.

Table 1. OoM of three exemplary OSH products.

OSH Product	Product openness	Process openness	OoM
echOpen	5	3	8
inMoov	3	0	3
POM	0	0	0

5. Discussion

The Open-o-Meter offers a pragmatic way to check how far the technical information delivered with a product allows anybody to study, modify, make and distribute it. It provides the general public with a simple checklist to appreciate the efforts made by a product originator to comply with the principles of open source. It also provides practitioners with a clear guideline to manage the product data along and after the product development process. The Open-o-Meter has proven to be a useful guide for companies to plan the integration of open source approaches in their business models, as indicated by the feedback of the Remodel programme [19] involving 10 different Danish companies. Beyond immediate usefulness, the Open-o-Meter also reveals the multifactorial and contextual nature of openness and provides further standardization effort with a basis to discuss which of these factors may be considered mandatory or optional.

While the Open-o-Meter allows for a more detailed assessment of product openness, it does not resolve the whole fuzziness of the concept of OSH. For example, while it is easy to verify whether CAD files are provided, it is much more difficult to check whether these CAD files cover the whole product (or at least the "creator's own contributions" to this product, as required by the OSWHA certification). Even knowing to what percentage the CAD files actually cover the product, where to raise the threshold between sufficient and insufficient? The same issues apply for other documentation items such as the BOM and the assembly instructions. How sufficient the provided documentation is, how easily it can be found, how comprehensible this documentation is for a given audience—these aspects cannot be measured easily. With this regards, the objective assessment of product openness would require a resource-intensive certification structure based on more refined criteria and third-party product review.

Also, different kinds of technologies may require different types of documents. While the replication of a mechanical assembly designed for 3D-printing may only require the disclosure of a few CAD files and an assembly sequence, those of a combustion engine may require extensive complementary information about materials and processes. In order to deal with this variability, standardization efforts in OSH may take advantage from the experience gained by sustainability certification schemes. Ecolabels such as the EU Ecolabel [20] or self-declaration schemes such as the Environmental Product Declarations [21] issue specific compliance rules for each product category. They can hence deliver a consistent label signposting the compliance with sustainability principles of different product types impacting sustainability in different ways.

The feasibility of creating such a third-party certification program for OSH is however questionable, due to associated monitoring and implementation costs clashing with the today's distributed and grassroots nature of OSH. The fundamental emphasis of the concept of OSH on trust and collaboration of OSH actors is moreover a strong argument in favor of for self-declaration.

6. Conclusions

Open Source Hardware (OSH) is an emerging approach to intellectual property management in product innovation and currently experiences the issues faced by any new concept seeking for settlement. The process of charting a consistent identity based on enforceable definitions and sharp compliance criteria is made difficult by the multifactorial and maybe ill-defined nature of openness and the consequent difficulty to draw a straight line between OSH and no-OSH products.

The present article underscores the imprecisions of existing definitions and standards and introduces a simple and flexible openness rating scheme referred to as the "Open-o-Meter". It allows assessing *how* open a physical product is instead of trying to determine *whether* it is open. This article also makes concrete propositions for future sharper criteria to assess compliance with OSH principles. These propositions are bound to significant investment in terms of standardization and administrative effort, whose feasibility will depend on how significant OSH will become in future public debate.

In the meantime, the Open-o-Meter already delivers a pragmatic approach for translating the programmatic definition of OSH into applicable terms both useful for practitioners and the general public.

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Appendices

Guidelines for OSH practitioners (accessed 15.03.2018)

- http://certificate.oshwa.org/;
- https://www.oshwa.org/sharing-best-practices/;
- https://github.com/jbon/Best-Practices-of-Open-Source-Mechanical-Hardware;
- https://openhardware.metajnl.com/about/submissions/#Structure;
- http://docubricks.com/best-practise-guide.jsp;
- http://opensourcedesign.cc/observatory

Documents used in OoM assessments (accessed 15.05.2018)

Product "echOpen":
- Licenses: http://www.echopen.org/licences.html
- CAD files: https://github.com/echopen/PRJ-medtec_kit/tree/master/mecanic
- ECAD files : https://github.com/echopen/PRJ-medtec_kit/tree/master/electronic
- BoM: https://github.com/echopen/PRJ-medtec_kit/tree/master/electronic/miscellaneous/general_BOM
- Assembly instructions: https://echopen.gitbooks.io/echopen_prototyping/content/stable/guide_hardware.html
- Contributing guide: https://echopen.gitbooks.io/echopen_prototyping/content/howto/howto.html
- GitHub repository: https://github.com/echopen

Product "inMoov"
- License: http://inmoov.fr/
- CAD files: http://inmoov.fr/inmoov-stl-parts-viewer/
- ECAD files: http://inmoov.fr/default-hardware-map/
- Assembly instructions: http://inmoov.fr/build-yours/
- Partial BoMs are spread within the assembly instructions

Product "POM"
- https://www.openmotors.co/renaultpomsignup/

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